Evaluation of NCEP Global Aerosol Forecast Model (Parallel NGACv2) against other models and observations

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Outline

1. Aerosol forecast at NWP
2. NGACv2 configuration and daily products
3. Observation and modeling datasets
4. Monthly comparisons
5. Case studies
6. Summary

Importance of including aerosol forecast capability at NWP

- The inclusion of the direct and indirect radiative effects of aerosols in high-resolution global numerical weather prediction (NWP) models is being increasingly recognized as important for the improved accuracy of short-range weather forecasts.

- It also produces quality aerosol forecast information that fulfills stakeholder requirements (such as, wild fires and volcanic eruption disrupt aviation)

- Provide lateral and upper boundary conditions for high resolution regional air quality predictions (better $PM_{2.5}$ forecast)

- Improve weather forecasts by taking into account of aerosol effects on radiation and clouds

- Improve the handling and use of satellite observations by properly accounting for aerosols effects during assimilation procedure

- Role of Saharan dust layer in tropical cyclone activities ?

NEMS GFS Aerosol Component (NGAC)

Development

- The **first global in-line aerosol forecast** system at NCEP (**Eulerian** T126L64)
- AGCM : NCEP's NEMS GFS
- Aerosol: GSFC's **GOCART**
- 120-hr dust-only forecast once per day (00Z), output every 3-hr
- ICs: Aerosols from previous day forecast and meteorology from operational GDAS
- **Implemented into NCEP Production Suite in September, 2012**

- Upgraded capability: **dust-only** system will be upgraded to **multi-species system** (dust, sea salt, sulfate, and carbonaceous aerosols) using real-time smoke emissions (from NESDIS)
- Additional 12Z cycle (currently only 00Z cycle)
- Enhanced dust products for
  - Aerosol multi-model ensemble (ICAP, WMO SDS-WAS at BSC)
  - Lateral boundary conditions for regional AQ model (ARL/EMC AQ group)
  - Monitoring long-range dust transport (WFO at Miami)
- New multi-species aerosol products supporting the following applications:
  - SST retrievals (NESDIS/STAR)
  - Solar energy predictions (SUNYA)
  - UV index forecast (NCEP/CPC)

NGACv2 (Parallel) Products

Provides 1x1 degree products in GRIB2 format twice per day (00Z and 12Z)

Product files (June2015-Current) and their contents include:

- **2D AOD : ngac.t00z.aod_$CH, CH=340nm, 440nm, 550nm, 660nm, 860nm, 1p63um, 11p1um, daily at 3-hour intervals up to 120hours**

- **ngac.t00z.a2df$FH, FH=00, 03, 06, ….120**
  - Total AOD and individual AOD's of dust, sea salt, carbonaceous aerosols, and sulfate at 0.55 micron
    - emission, sedimentation, dry deposition, and wet deposition fluxes (Kg/m2/sec)
  - Single scatter albedo and asymmetric factor for total aerosols at 0.34 micron

- **3D AOD : ngac.t00z.a3df$FH, FH=00, 03, 06, ….120**
  - Pressure, temperature, relative humidity at model levels
  - Mixing ratios (kg/kg) for aerosol species at model levels (64 Levels, ~1000 to 0.1 mb)
  - Dust and Sea-salt mixing ratio for 5 bins, BV and OC (hydrophobic and hydrophilic), Sulfate dry

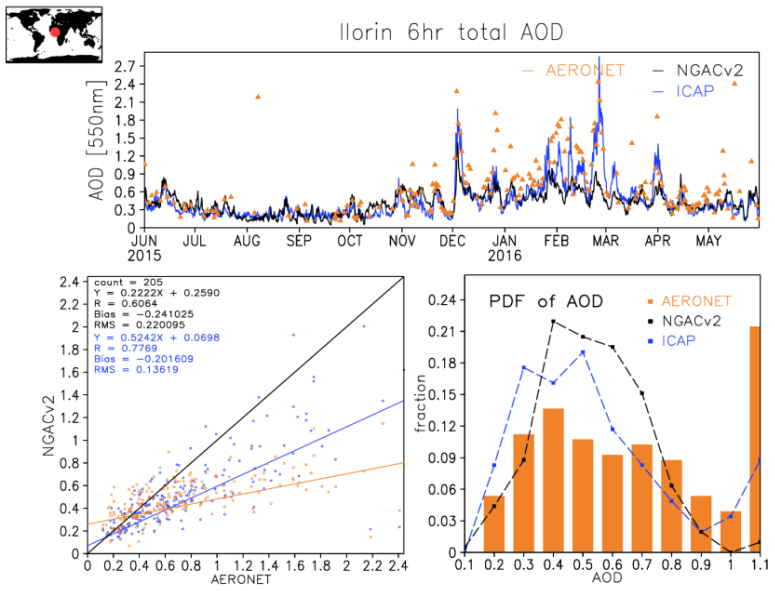
Observation and modeling datasets

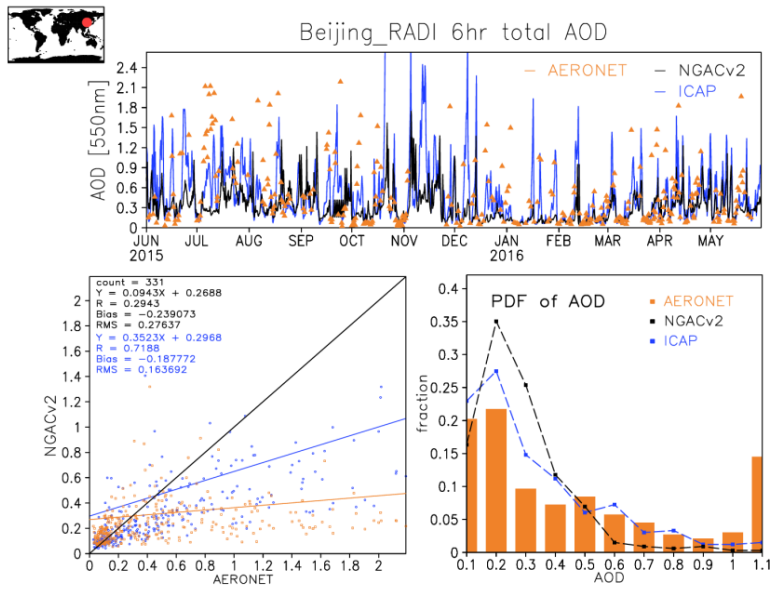
Types of Data	Data Source
In-situ observation	**AERONET** Level 1.5/2.0 from NASA GSFC
Satellite data (gridded)	**VIIRS (Daily)** : EPS VIIRS at 1 degree from NESDIS/STAR and 0.25 degree near-real time AOD at 550nm from NESDIS ftp site **MODIS (Daily)** Aqua (Collection 6, combined DT/DB) AOD at 550nm from GES DISC **MISR (Daily)** AOD at 550nm **GOME2 (Daily)** : Absorbing Aerosol index **CALIPSO (Monthly)** : Level 3 gridded; 532nm aerosol extinction profiles (dust, smoke and total)
Modeling data	**NGACv2** from NOAA/NCEP **ICAP-MME** ensemble from US NRL (Total and dust AOD) daily 6 hourly forecast intervals up to 5 days **MERRA-2** monthly AOD for Total and aerosol species from GSFC

AERONET L1.5 vs. NGACv2

Sheng-Po Chen at SUNY, Albany provided the following analysis

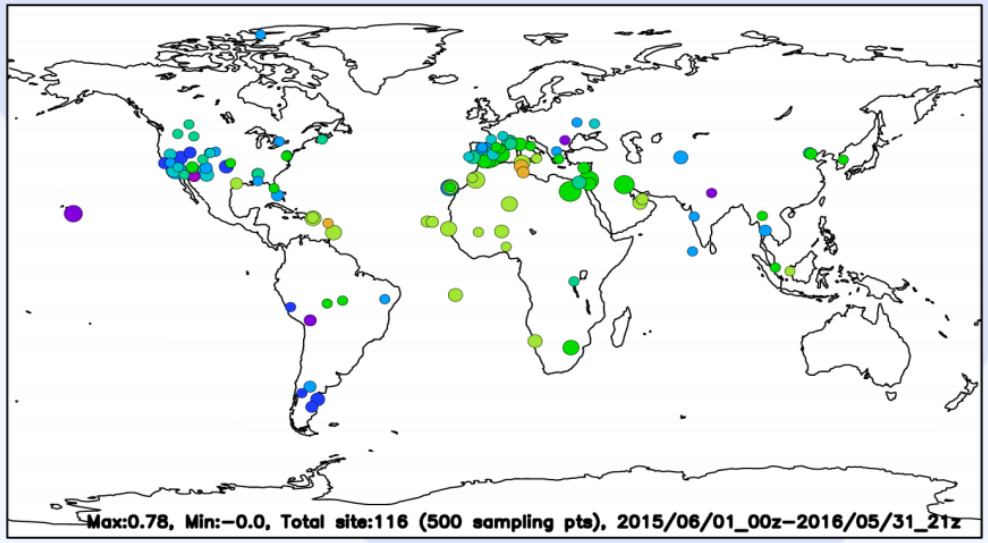
- Aeronet L1.5 AOT_{550} is first calculated from AOT_{440} and AOT_{675}
- 1-h time window bins centered at NGAC model output times of 0, 3, 6, 9, 12, 15, 18, 21 UTC are created to pair NGAC and Aeronet.
- Analysis period : 2015/06/01 00z – 2016/05/31 24z.
- Selection criteria : AOT < 2.5; available data count > 500. Total 116 sites (Africa 23, Arabian 7, N.A. 35, S.A. 13, EU 26, Asia, Polar 1)



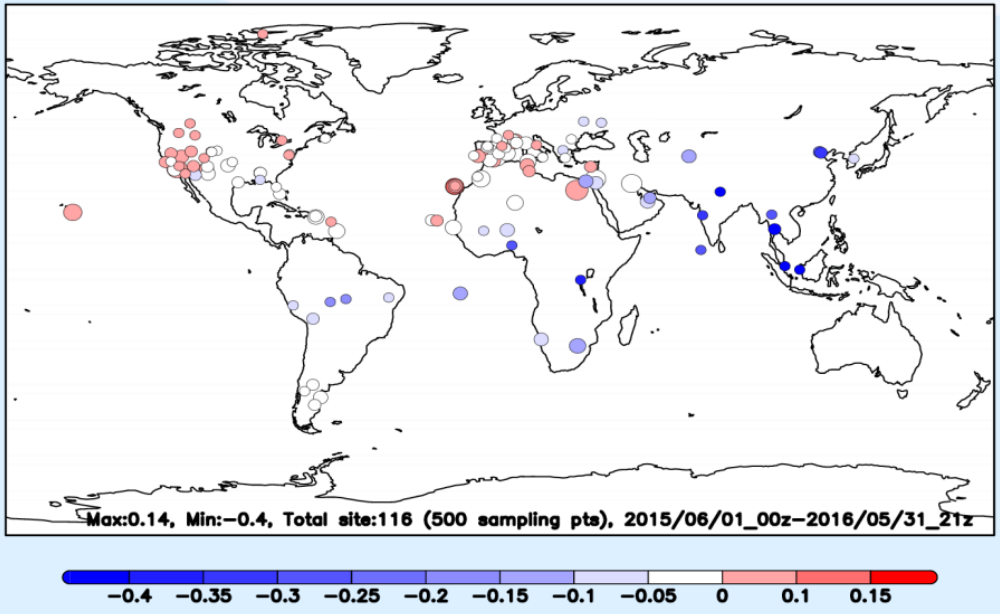


AERONET L1.5 vs. NGACv2

Correlation Coefficient of NGACv2 vs. AERONET AOD550



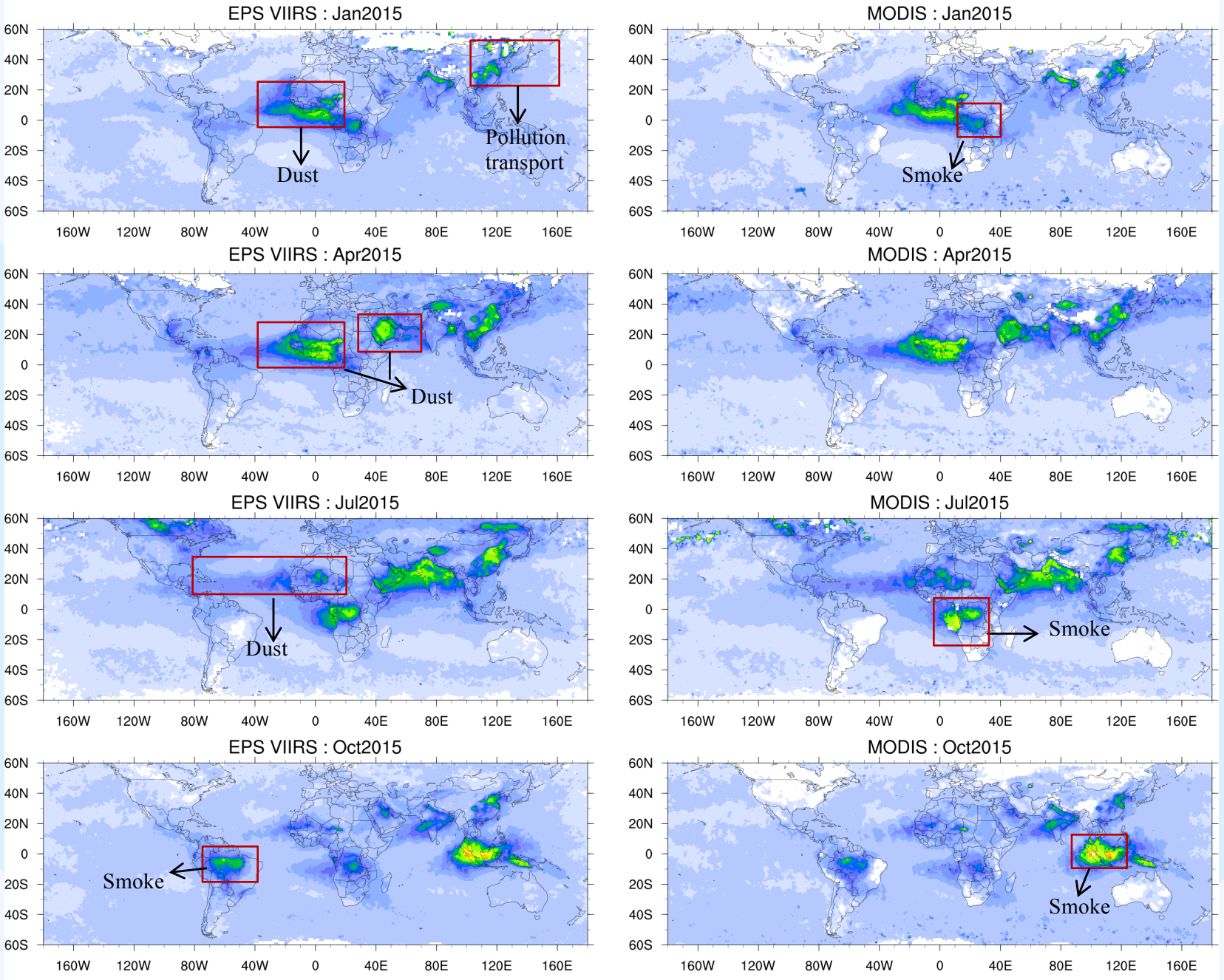
Bias of NGACv2 vs. AERONET AOD550



Courtesy : Sheng-Po Chen

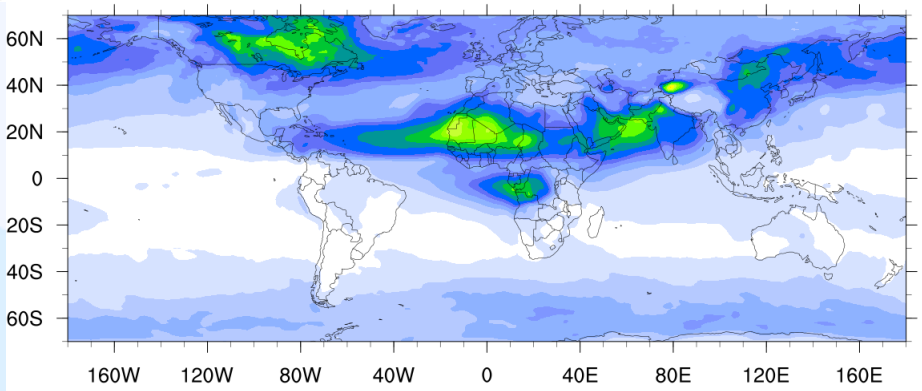
Monthly variations of global aerosol sources and transport

Monthly mean AOD at 550nm

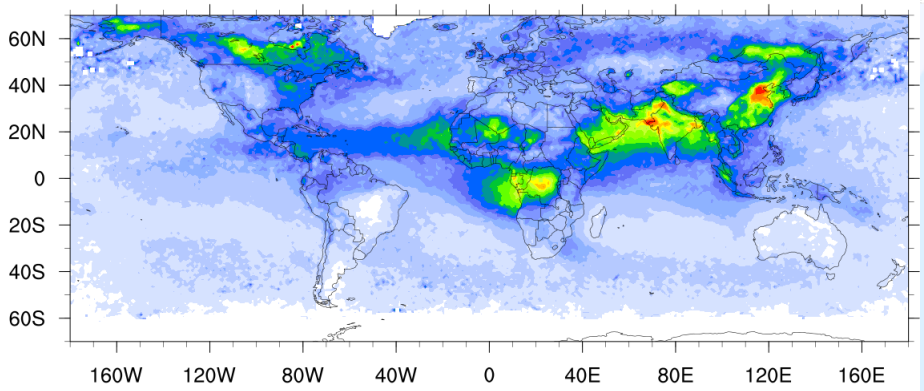


July , 2015

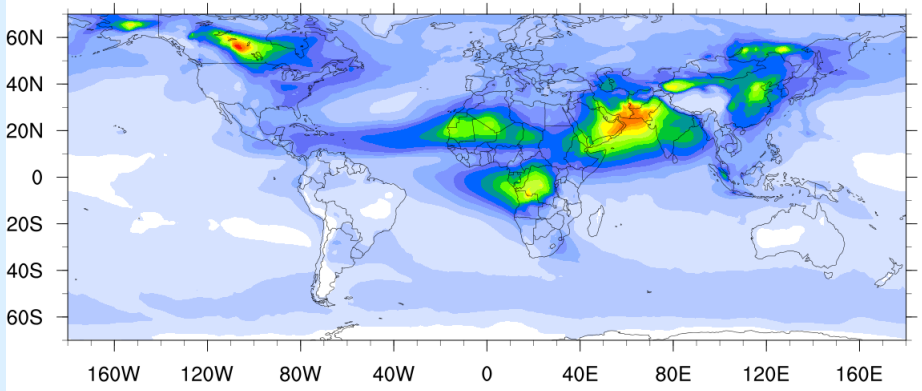
NGACv2 : Total AOD



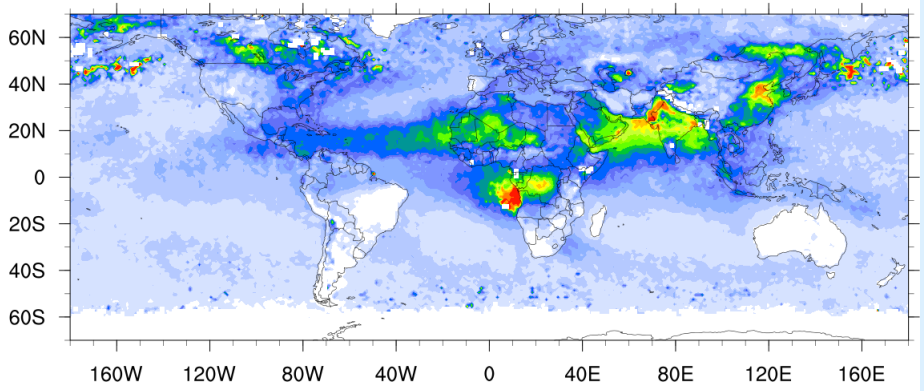
EPS VIIRS : Total AOD



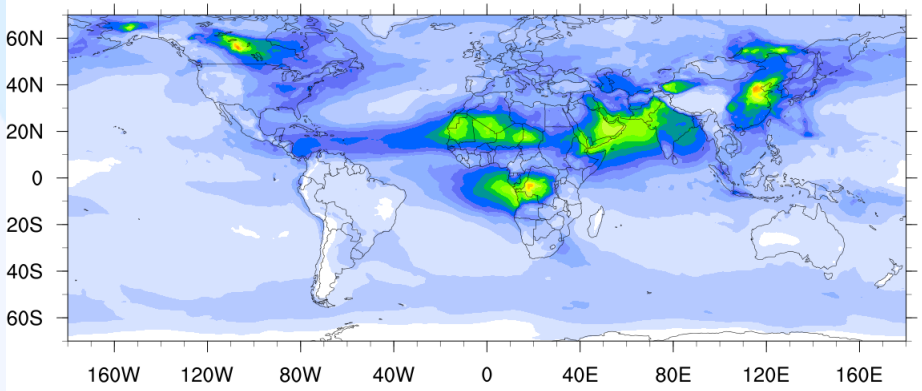
ICAP-MME : Total AOD



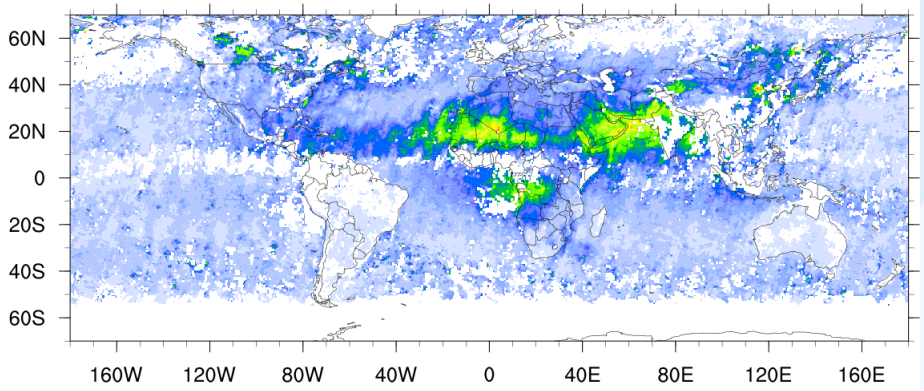
MODIS : Total AOD

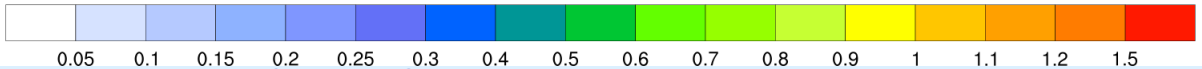


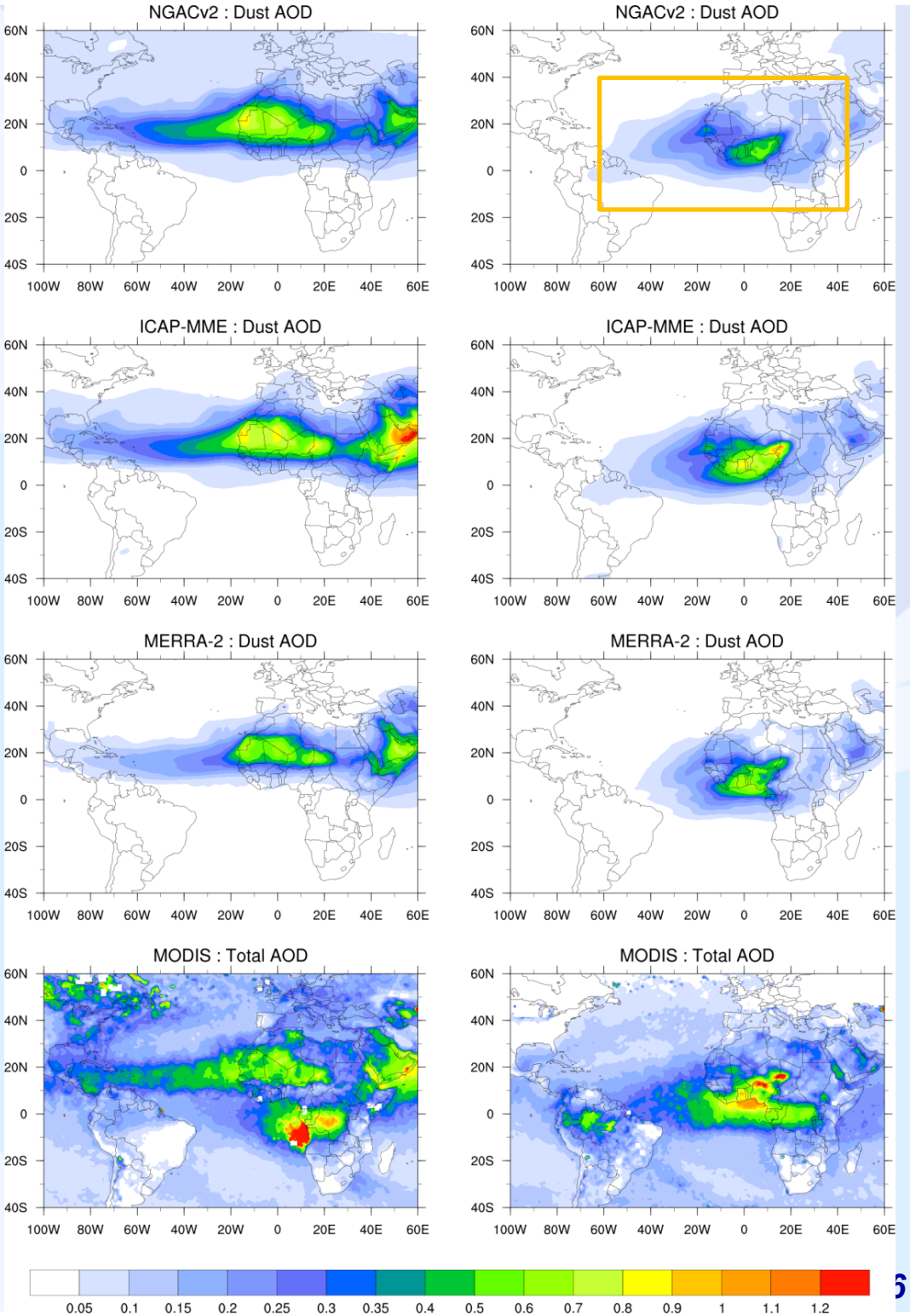
MERRA-2 : Total AOD



MISR : Total AOD





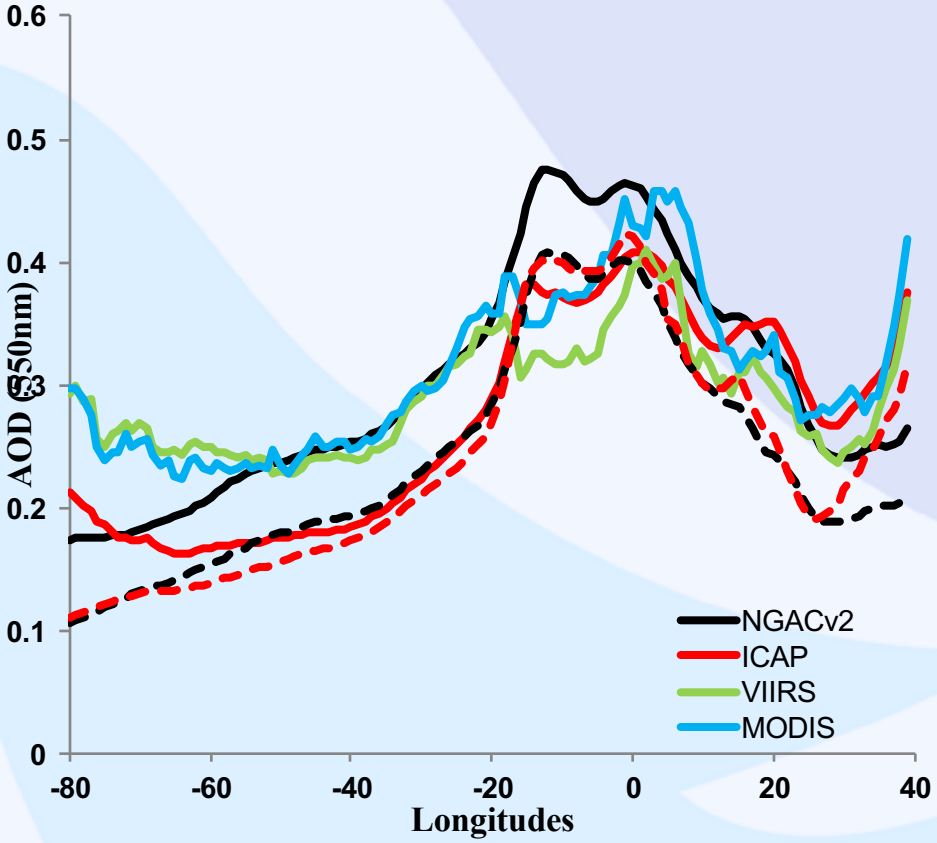


August, 2015

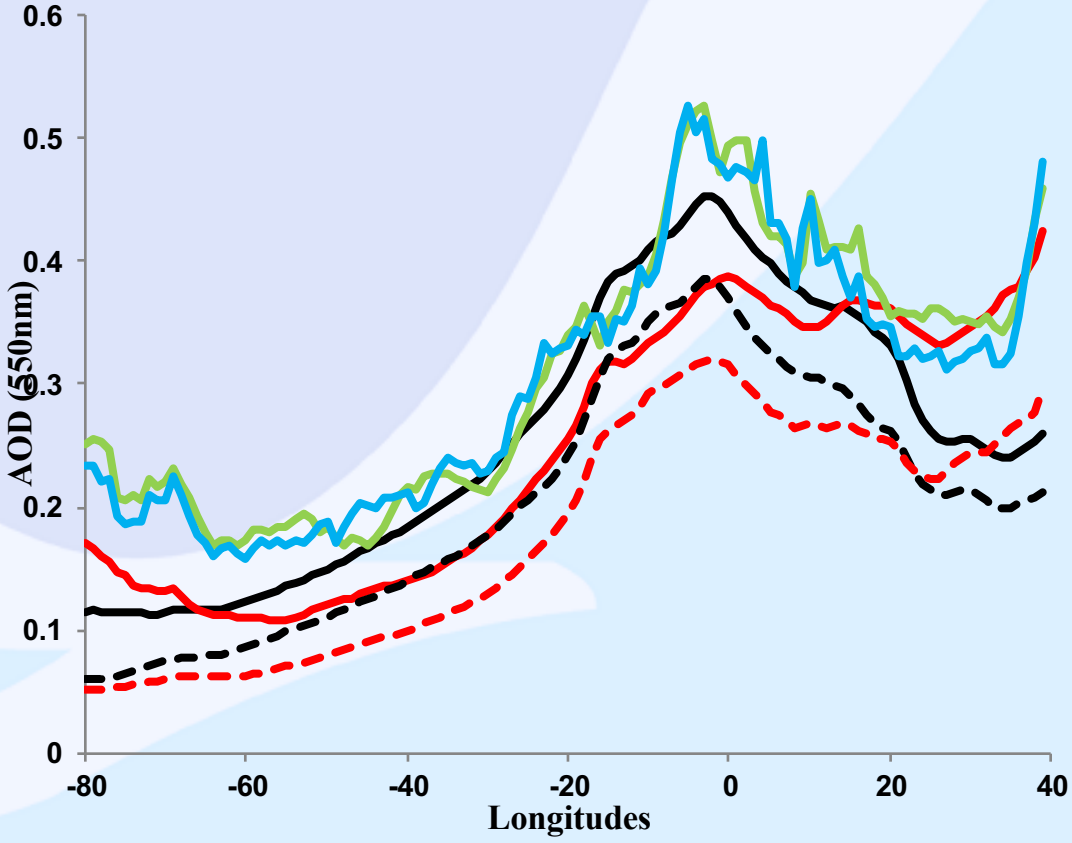
January, 2016

❖ NGACv2 captures change of Dust transport path across Africa in summer and winter months.

Total and Dust AOD over African coast (averaged between 0-35N)



July, 2015



August, 2015

❖ Both models under predict in August compare to July

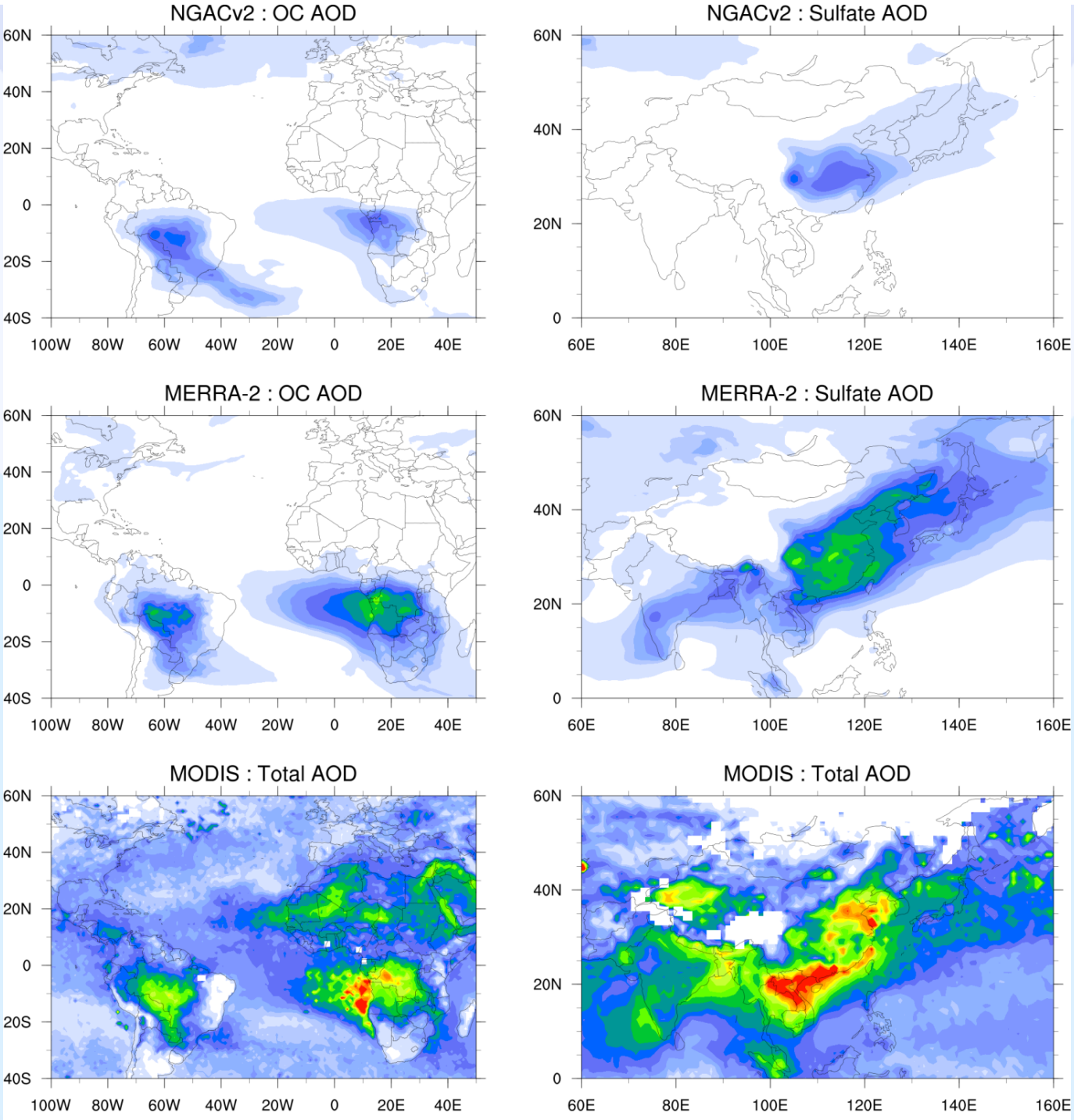
24-hour **dust AOD** forecast correlation between NGACv2 and ICAP-MME

	Global	Sahara	Middle East	Asia
		[0-40N; 70W-30E]	[0-35N; 35E-65E]	[0-60N; 50E-150E]
June, 2015	0.714	0.846	0.825	0.769
July, 2015	0.601	0.806	0.752	0.69
Aug, 2015	0.559	0.787	0.77	0.7
Sep, 2015	0.48	0.679	0.548	0.546
Oct, 2015	0.579	0.779	0.694	0.702
Nov, 2015	0.556	0.71	0.669	0.556
Dec, 2015	0.585	0.617	0.72	0.52
Jan, 2016	0.52	0.736	0.799	0.512
Feb, 2016	0.578	0.82	0.824	0.612
Mar, 2016	0.672	0.773	0.801	0.754
Apr, 2016	0.699	0.847	0.807	0.755
May, 2016	0.682	0.765	0.863	0.789
June, 2016	0.685	0.76	0.684	0.725

OC and Sulfate

September, 2015

April, 2016



24-hour **Total AOD** forecast correlation between NGACv2 and ICAP-MME

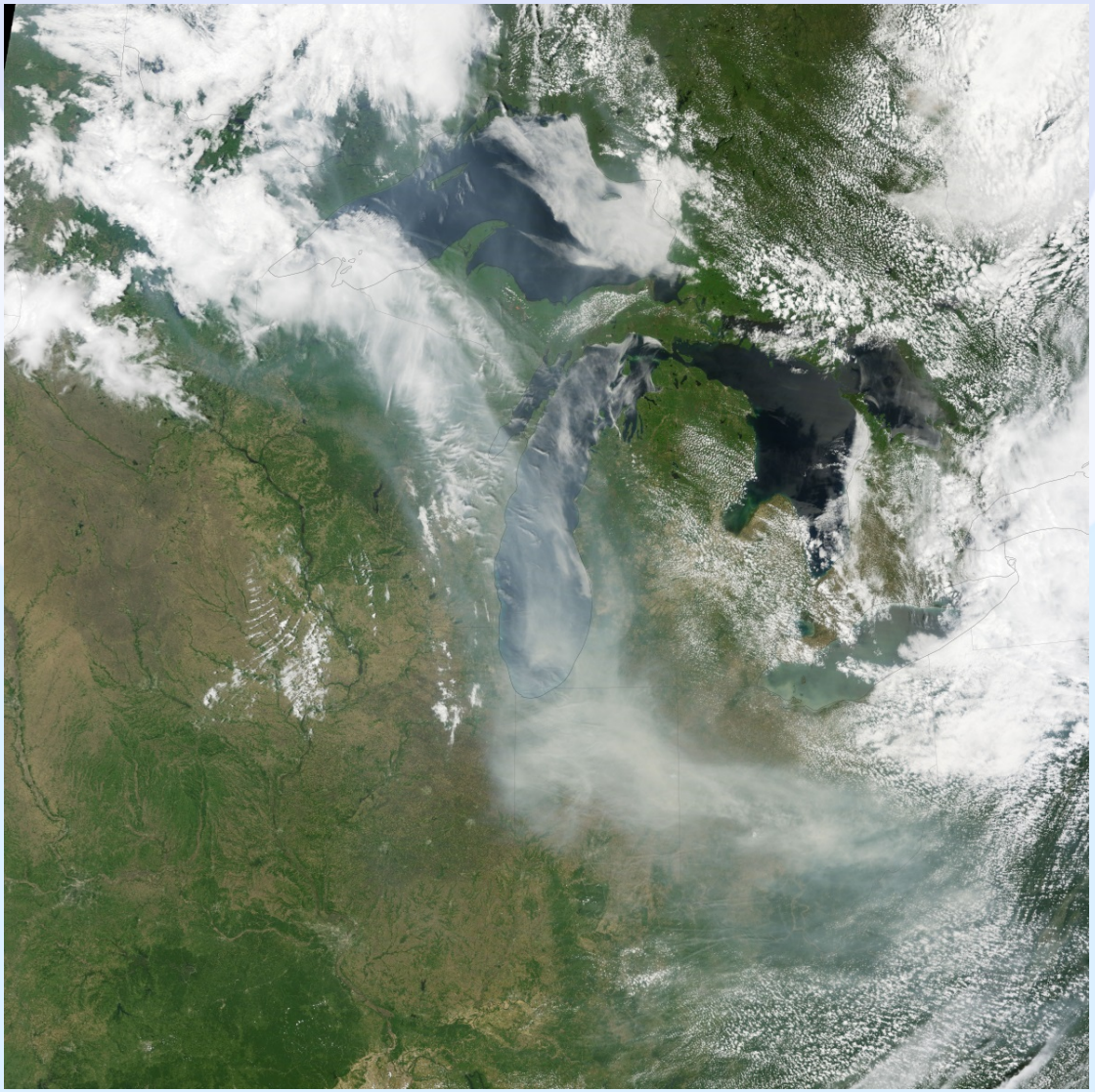
	Global	N. America	S. America	Asia	Africa	Europe
		[0-70N; 160W-40W]	[10S-60S; 100W-20W]	[10S-60N; 50E-160E]	[40S-45N; 30W-60E]	[45N-80N; 20W-40E]
June, 2015	0.577	0.568	0.535	0.543	0.727	0.516
July, 2015	0.547	0.589	0.512	0.563	0.643	0.469
Aug, 2015	0.524	0.451	0.594	0.532	0.616	0.48
Sep, 2015	0.433	0.431	0.429	0.398	0.508	0.332
Oct, 2015	0.529	0.457	0.612	0.53	0.64	0.49
Nov, 2015	0.457	0.468	0.471	0.453	0.538	0.34
Dec, 2015	0.515	0.501	0.595	0.432	0.623	0.413
Jan, 2016	0.485	0.487	0.512	0.531	0.648	0.362
Feb, 2016	0.509	0.533	0.491	0.55	0.654	0.553
Mar, 2016	0.509	0.487	0.521	0.495	0.654	0.523
Apr, 2016	0.542	0.48	0.581	0.479	0.666	0.615
May, 2016	0.561	0.433	0.55	0.486	0.661	0.405
June, 2016	0.518	0.425	0.545	0.475	0.644	0.38

Selected list of aerosol case studies

Events	Timeline	Region
Dust	1-5th April, 2015	Middle East
Forest fire	17-21st April, 2015	Alaska
Dust	25-30th April, 2015	East Asia
Dust	16-20th May, 2015	India
Dust	8-13th May, 2015	Western Sahara
Dust	3-7th & 10-19th June, 2015	Trans-Atlantic dust originated from Sahara
Smoke	27June -4th July, 2015	Canada and North America
Sulfate	13th -16th September, 2015	Europe
Dust and Smoke	21-27th December, 2015	Western Africa

CASE #1

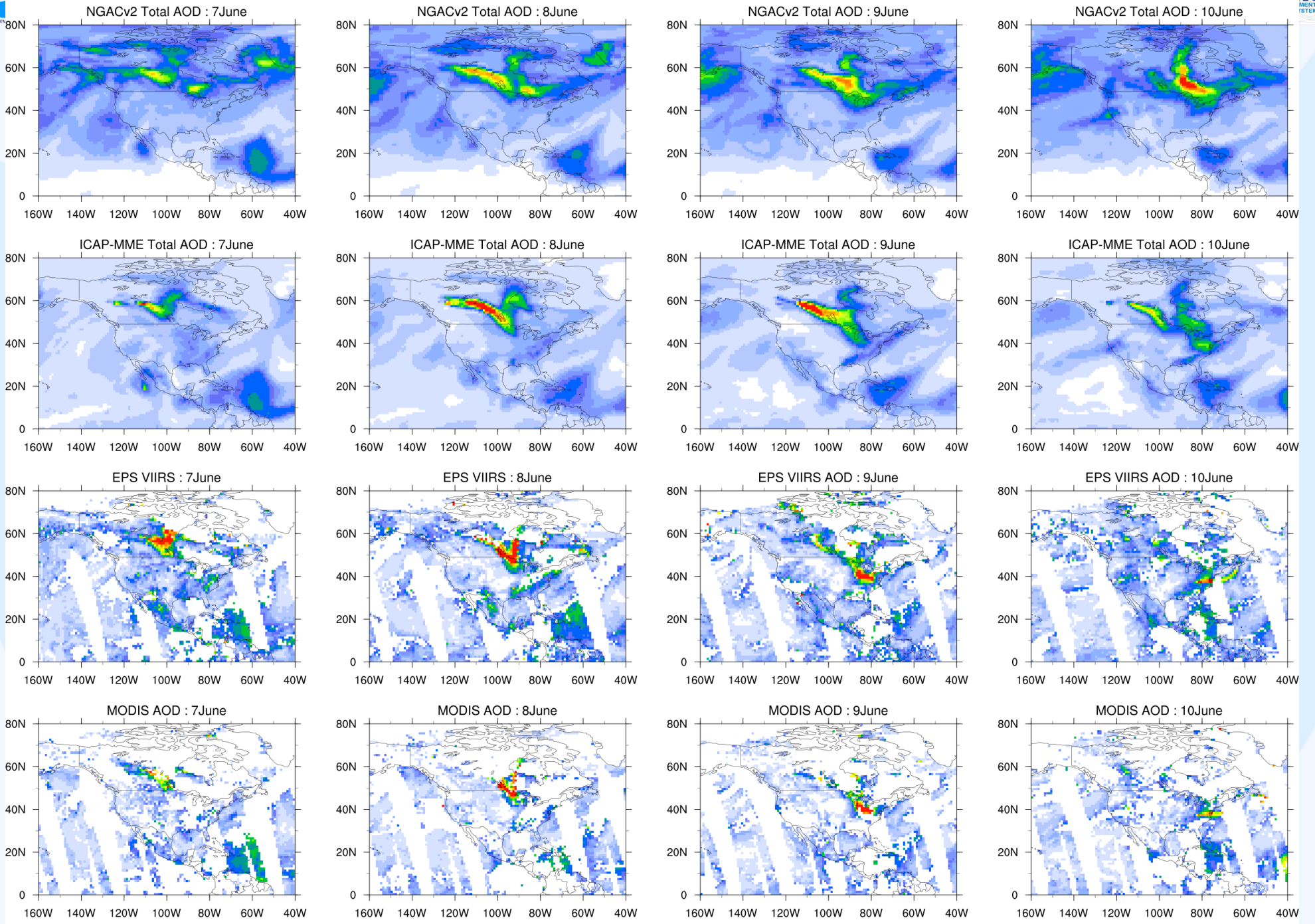
Terra MODIS True color image on 9th June, 2015



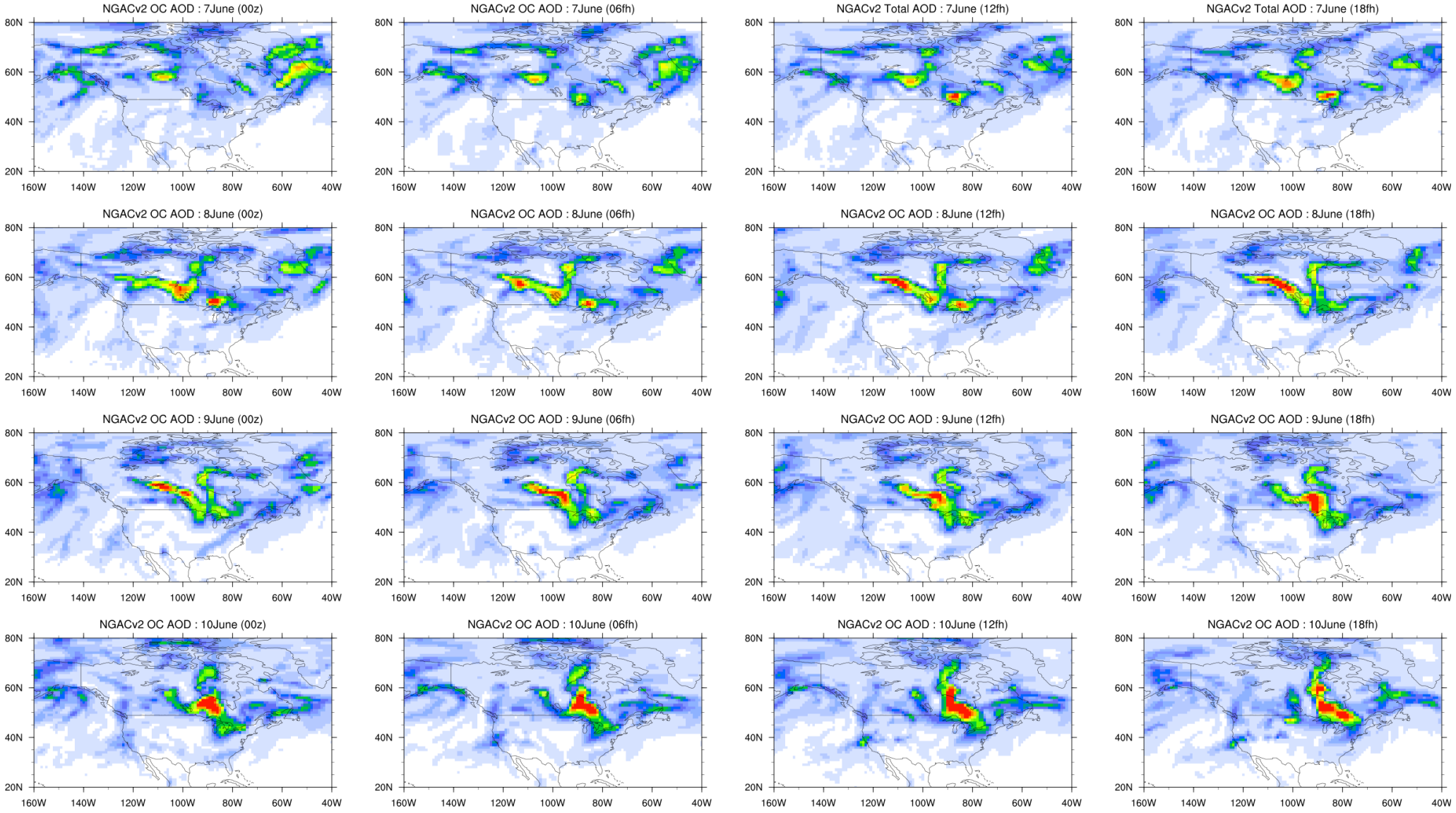
Smoke plume was between 2-5km in altitude

More about this smoke : http://www.chicagotribune.com/news/local/breaking/ct-orange-sun-chicago-canada-fires-met-20150609-story.html

7-10th June,2015 (Total AOD at 550nm)

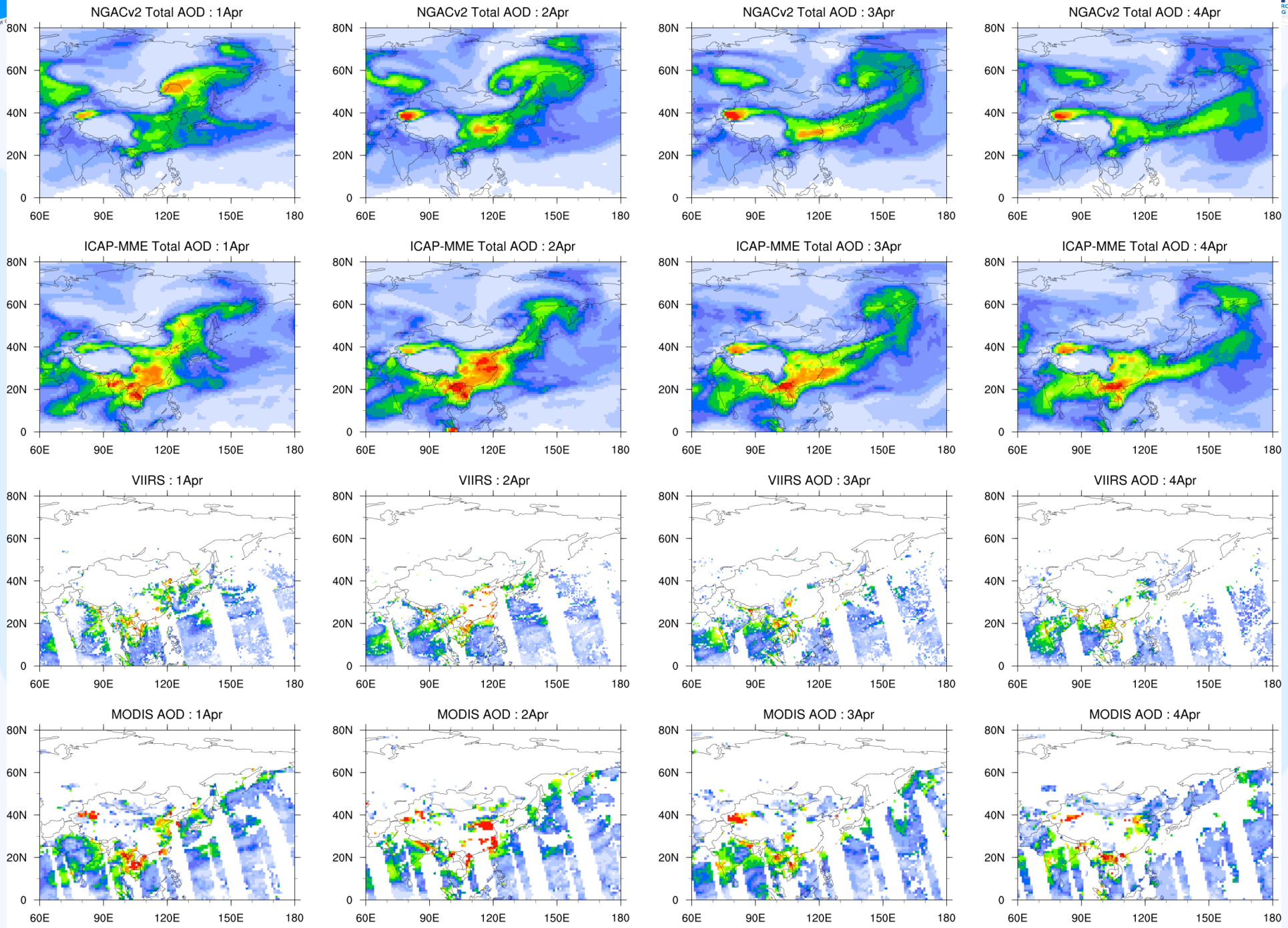


7-10th June,2015 (OC AOD at 550nm)

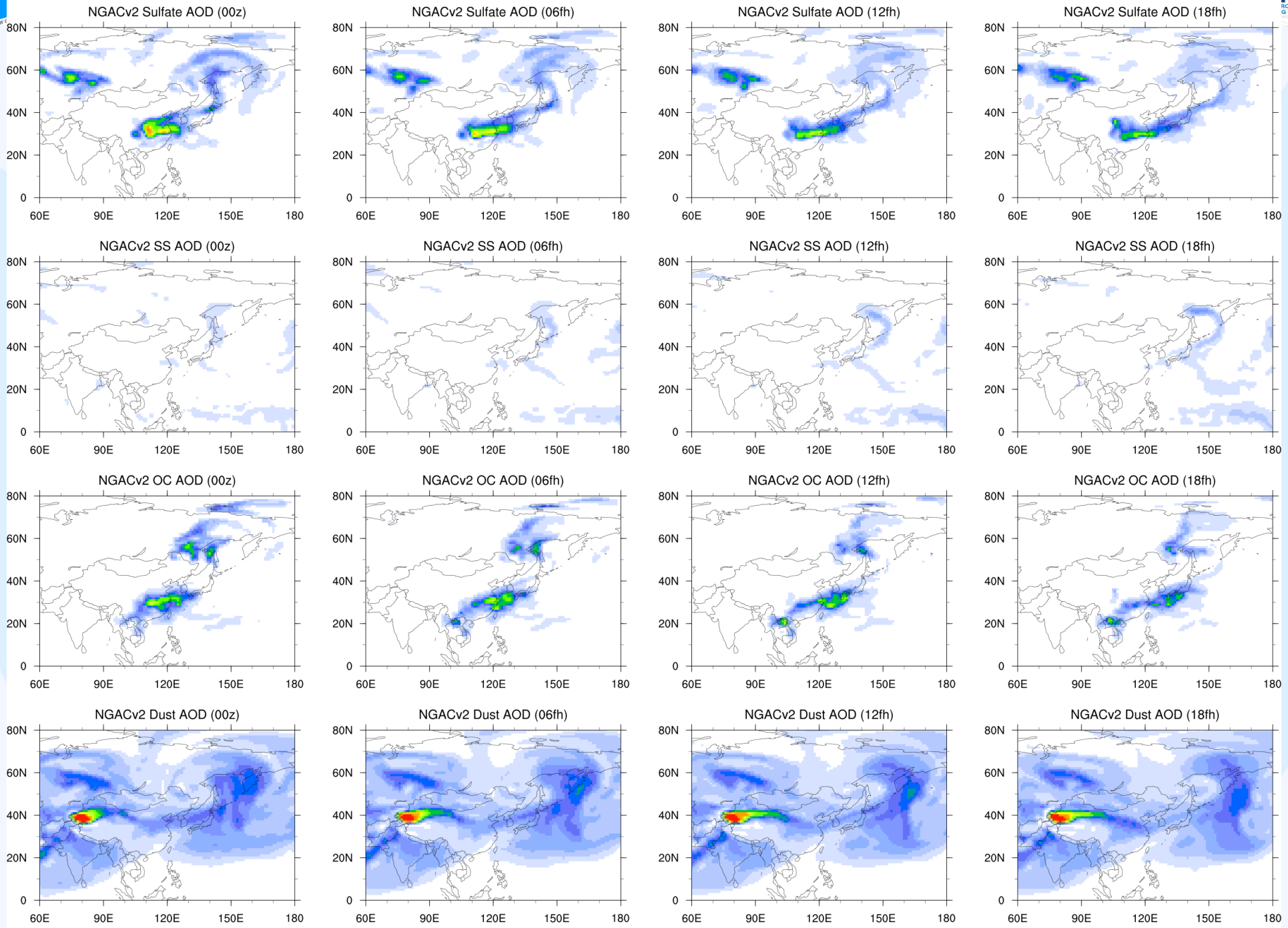


CASE #2

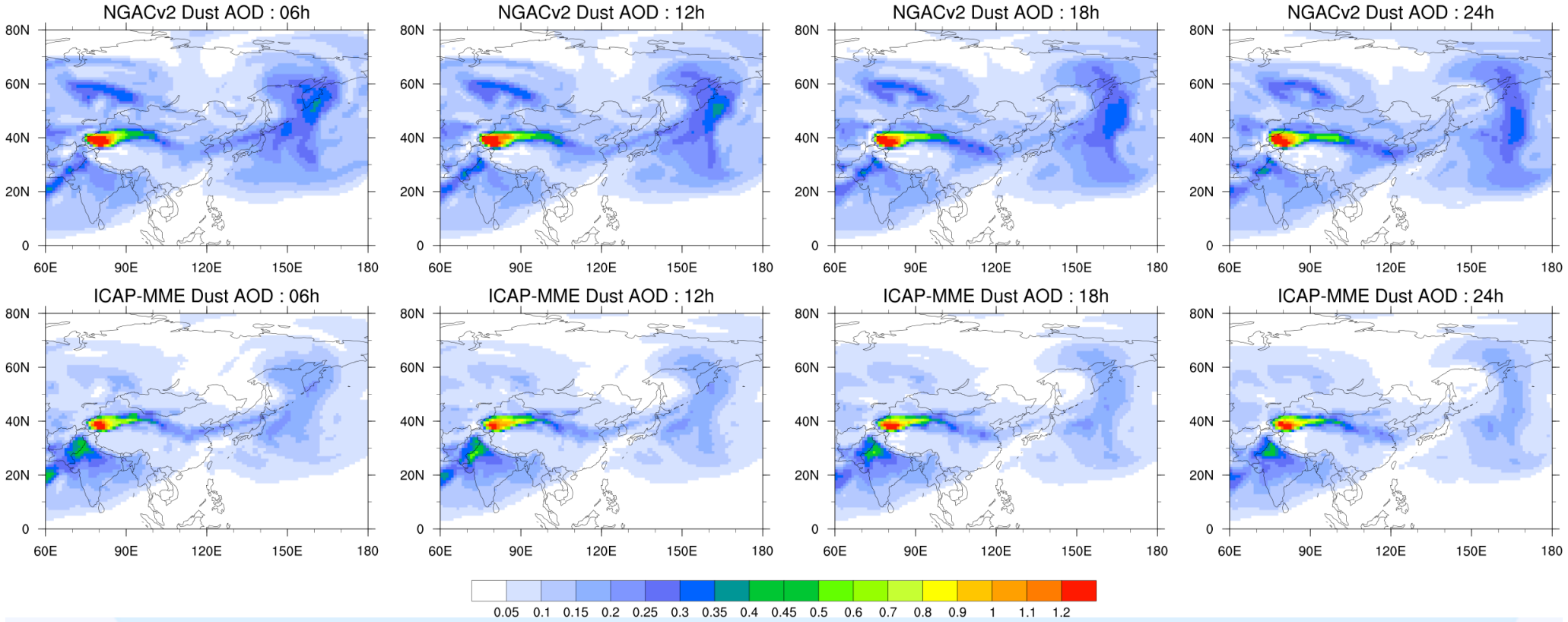
1-4th April,2016 (Total AOD at 550nm)



3April,2016 (AOD at 550nm)



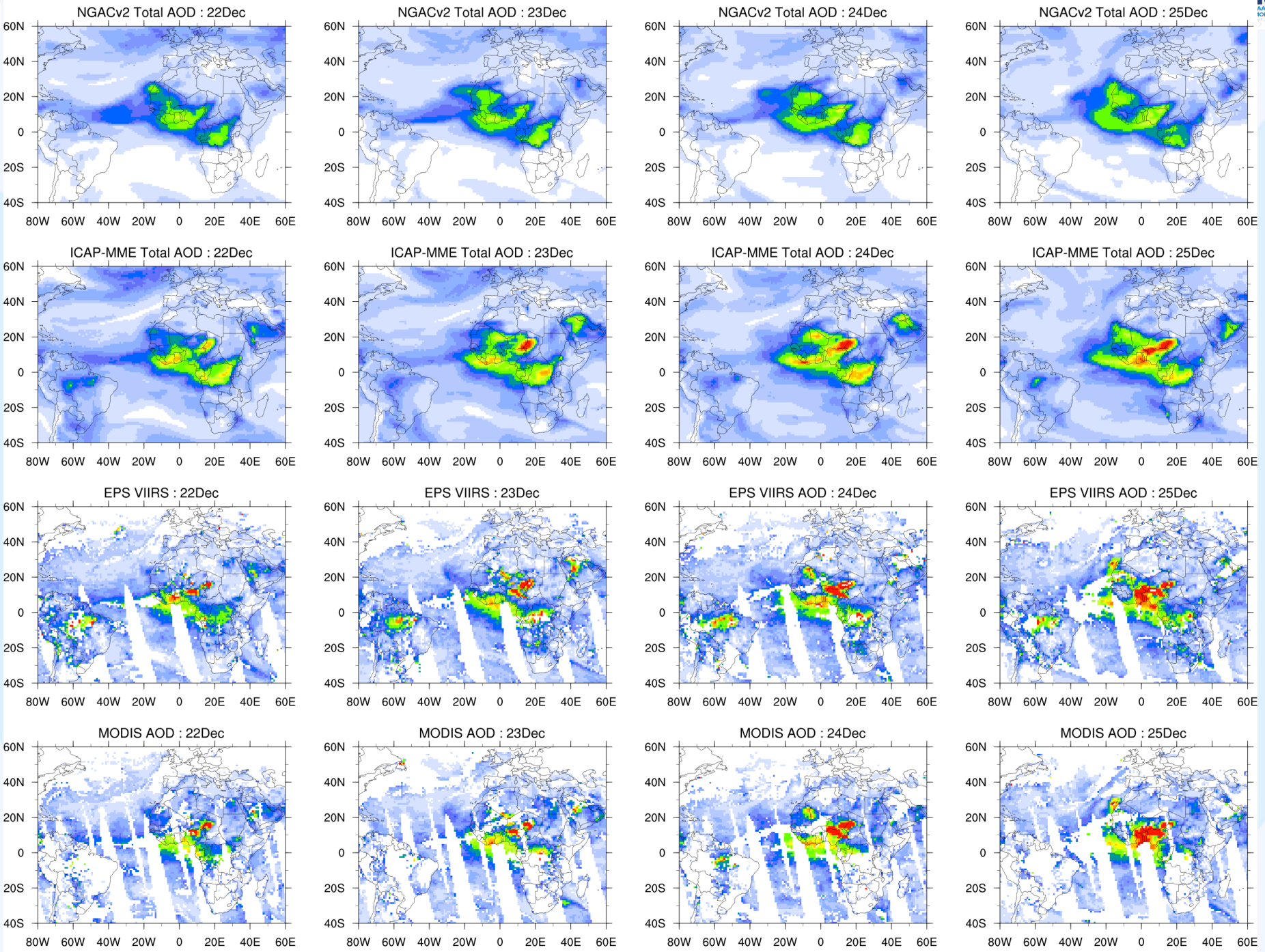
3rd April,2016 (Dust AOD at 550nm)



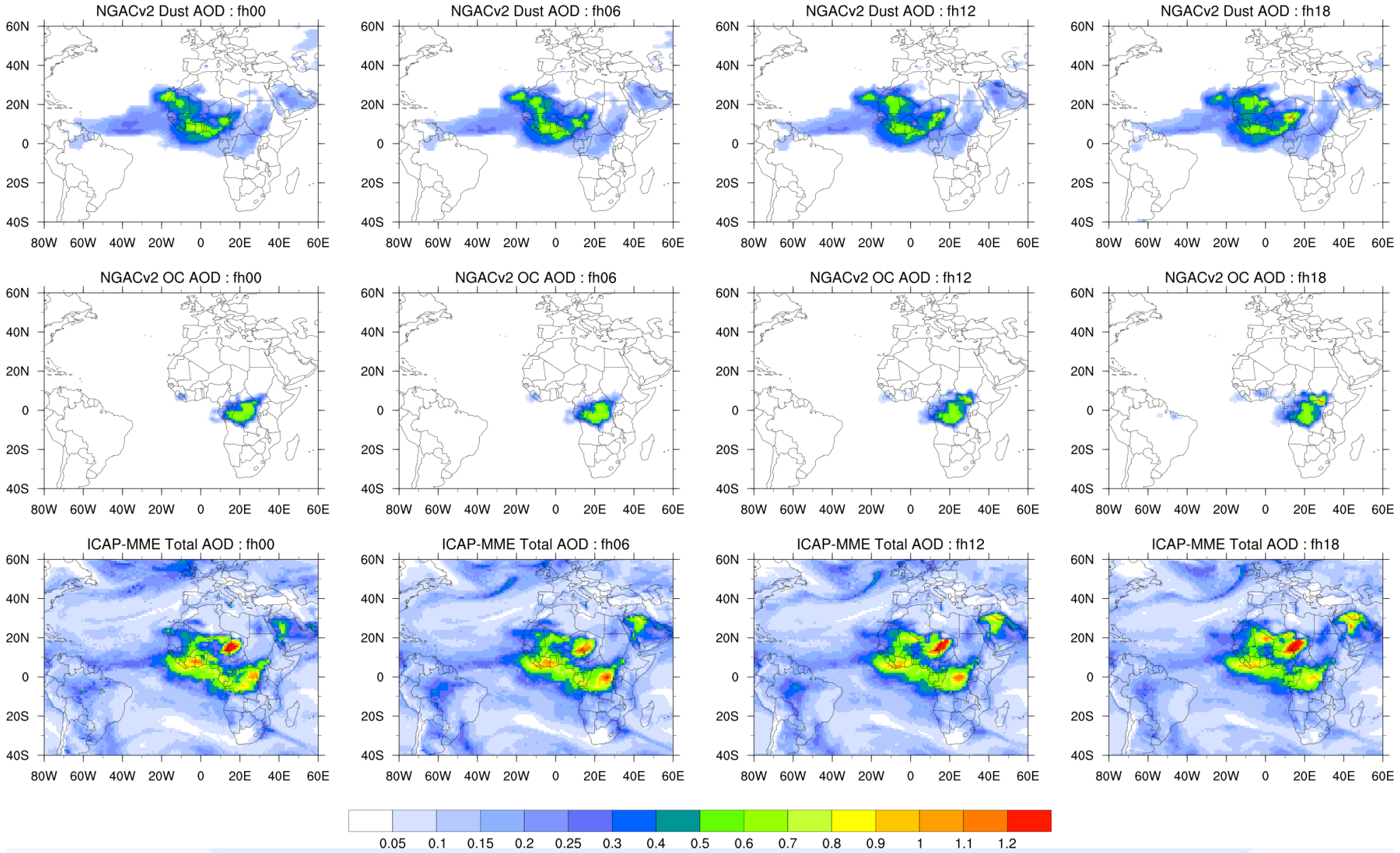
Mixture of Dust, OC, Sulfate transported to USA

CASE #3

22-25th December,2015 (Total AOD at 550nm)

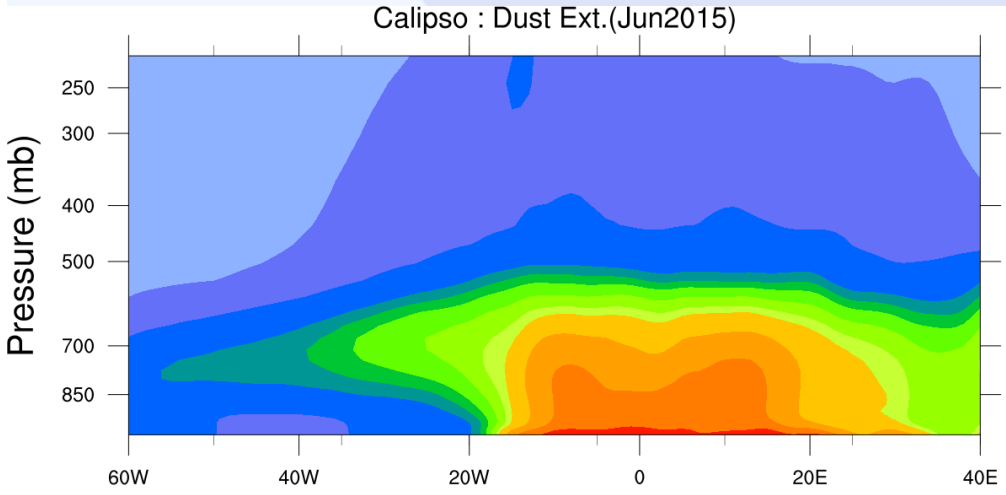


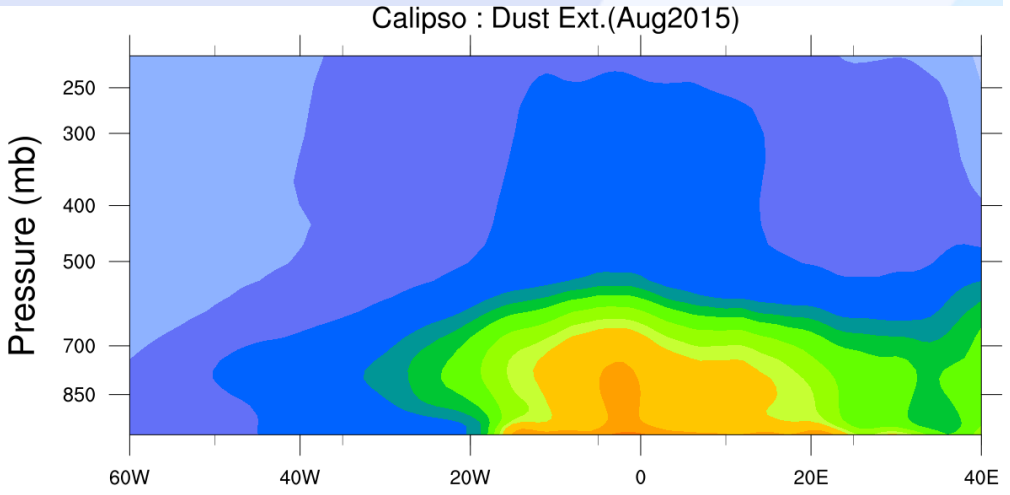
23 December, 2015 (Dust AOD at 550nm)

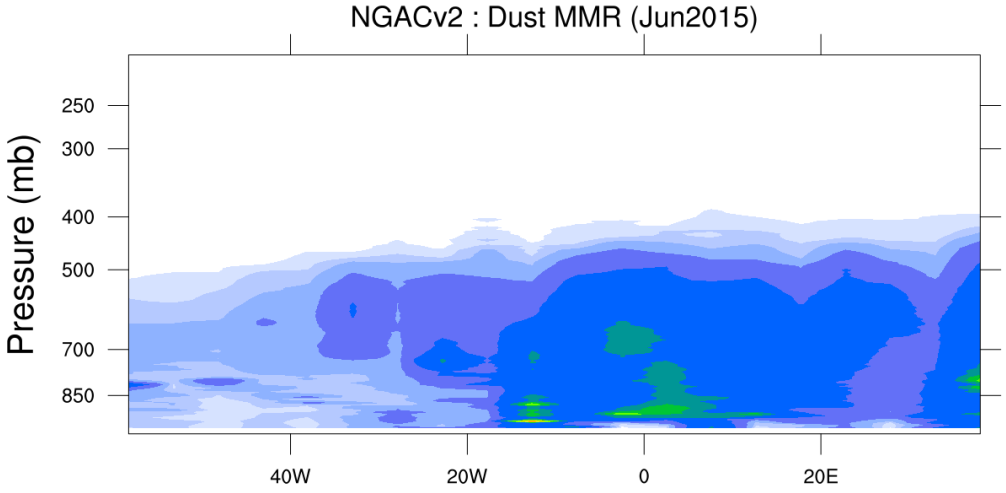


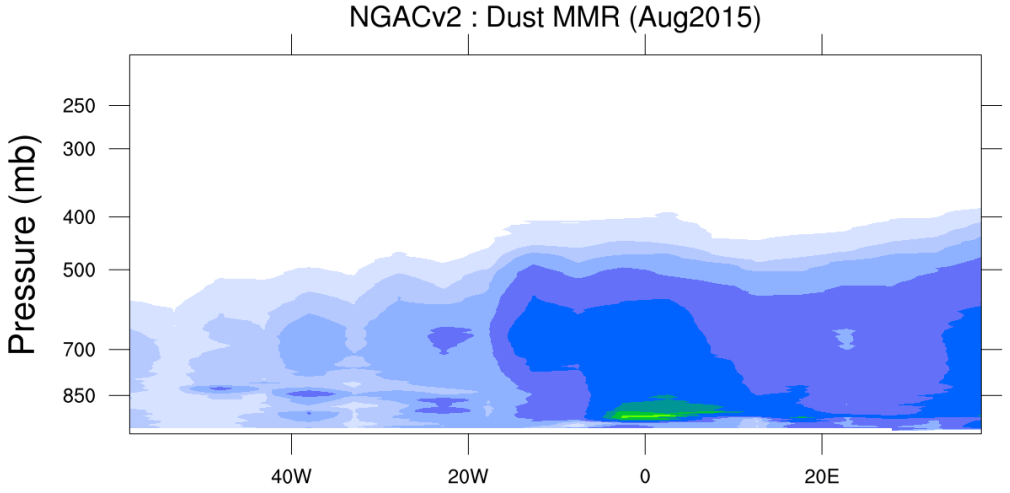
6 hourly forecasts on December 23rd show both dust and smoke activity

CALIPSO Dust extinction profile (532nm) vs. NGACv2 Dust MMR



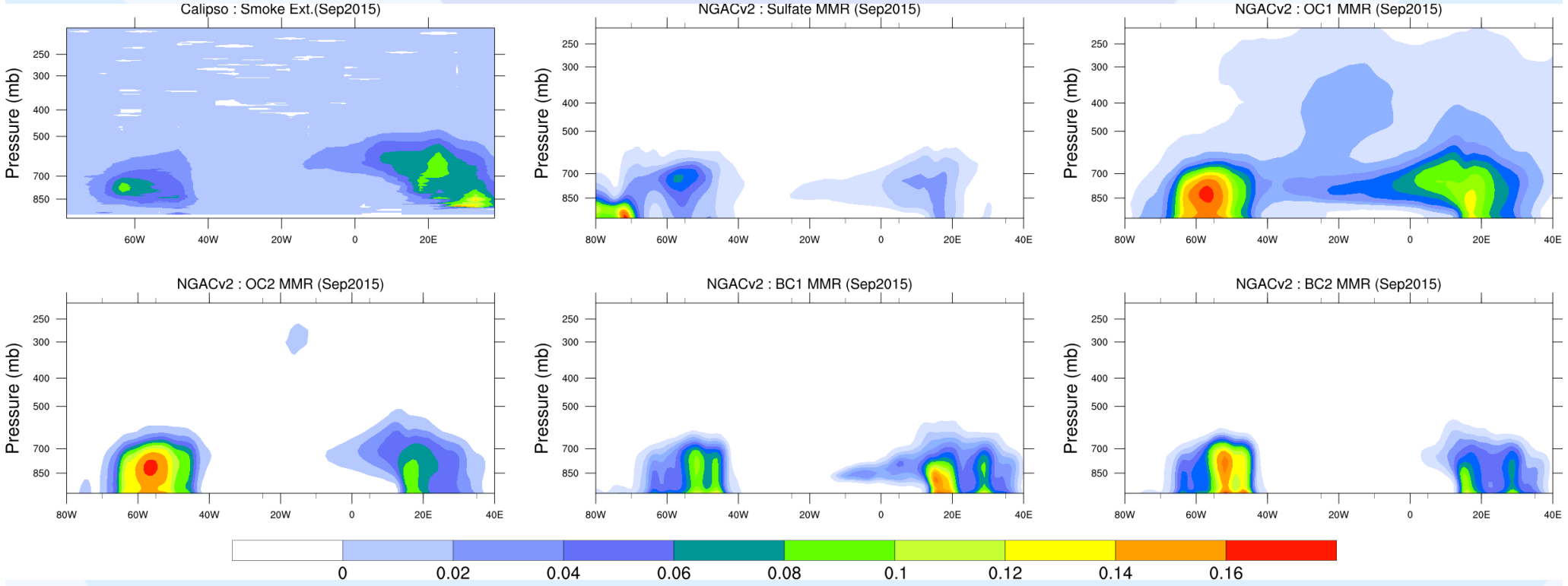






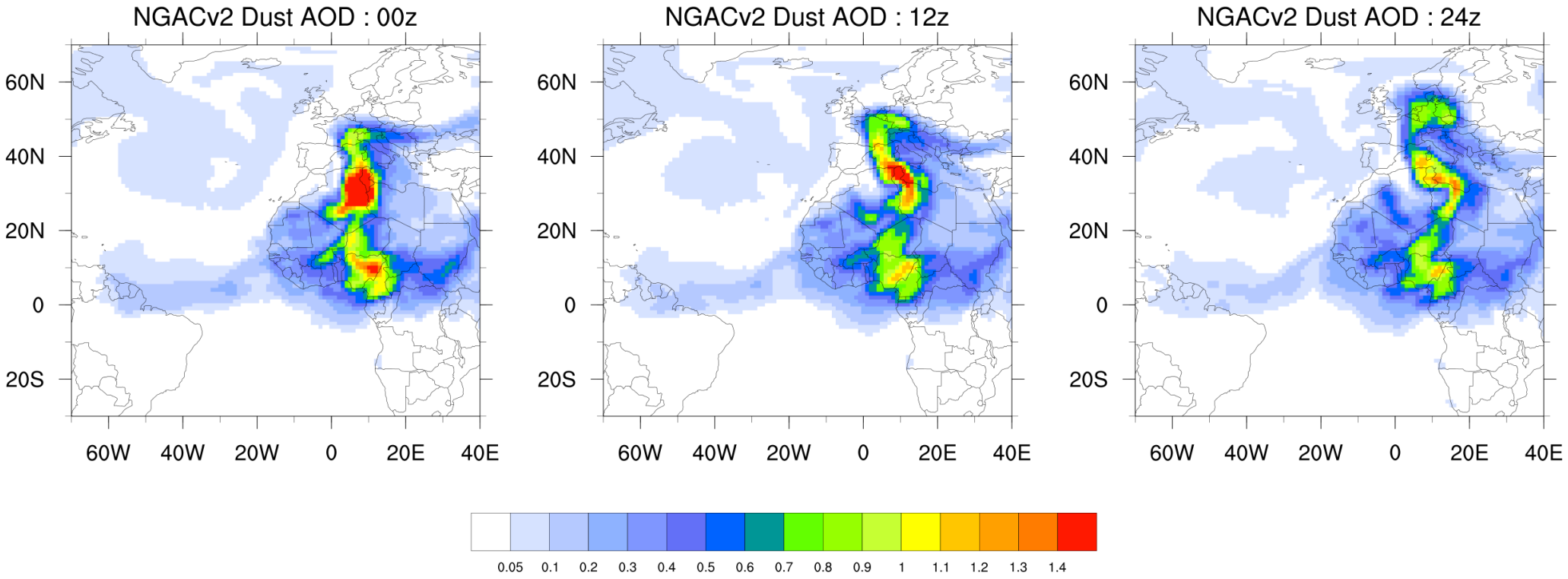
Night time, All sky, monthly Level 3 CALIPSO data taken from ASDC

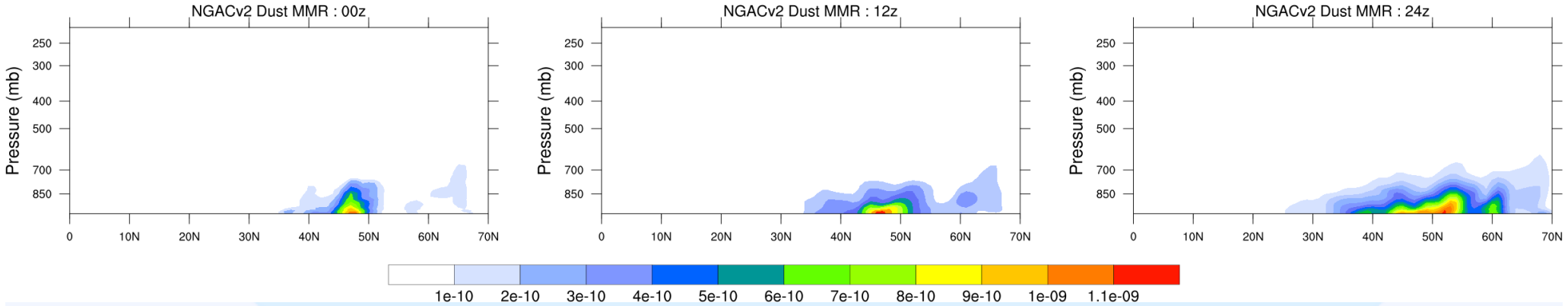
CALIPSO Smoke extinction profile (532nm) vs. NGACv2 OC, BC and Sulfate MMR



*OC, BC and Sulfate MMR are multiplied to bring into common scale

2nd April, 2016 (Dust AOD at 550nm)





SUMMARY

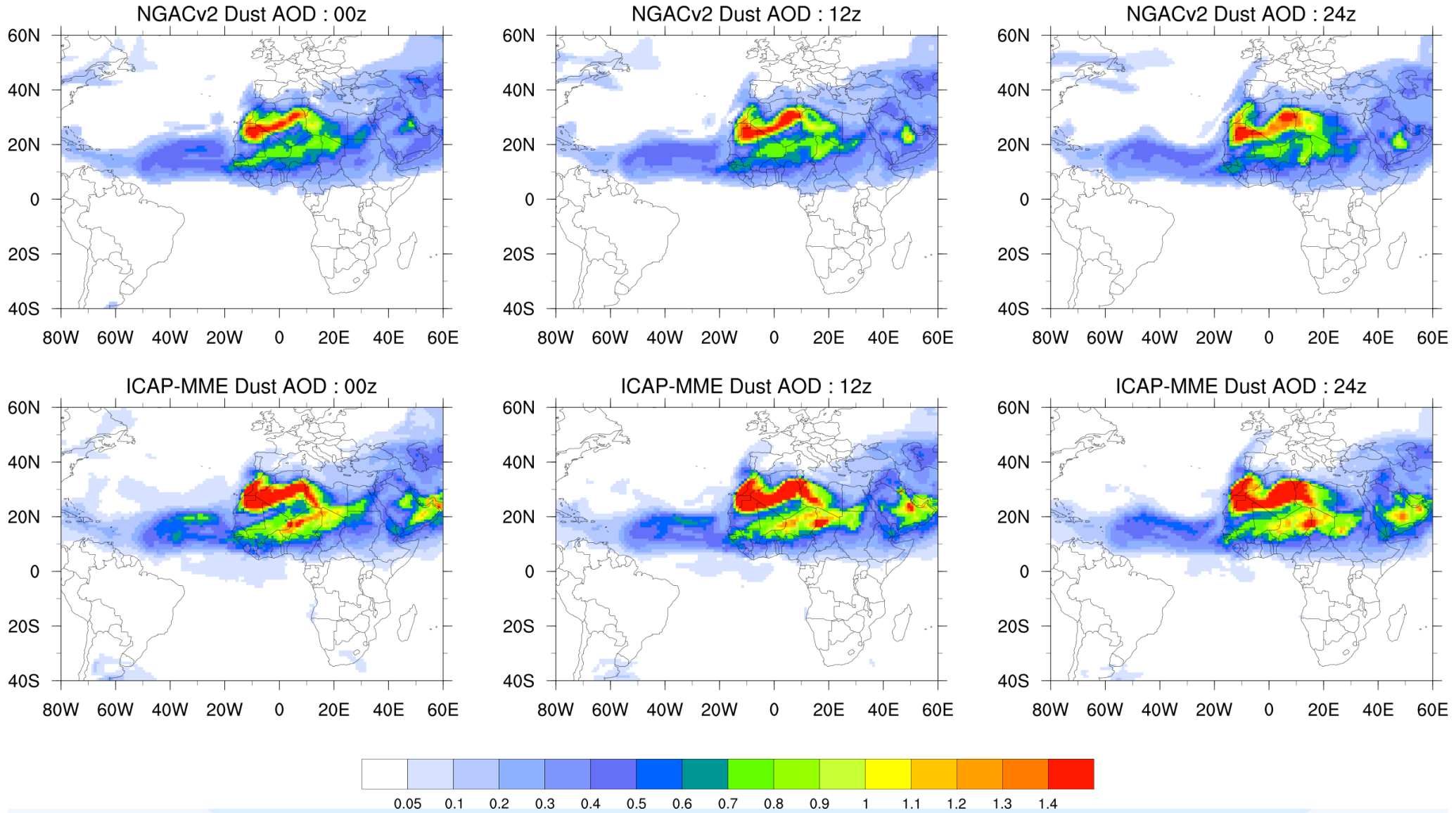
- Currently monitoring parallel NGACv2 runs and evaluated against ground based, satellite and other models for total AOD and for individual aerosol species as well.
- We are looking into individual case studies as well as monthly means to check parallel NGAC v2 performance.
- 3D aerosol evaluation using MPLNET/AHSRL at available surface locations will be investigated further
- Utilize L2 CALIPSO data to study some of the long-distance aerosol transport cases
- Some of the differences between NGAC V2 and other models can be attributed to aerosol DA capability in those models
- Our efforts on tuning NGAC V2 and refining scaling factor in GBBEPx may have limited impact on reducing NGAC2 vs MERRA2 differences.

Acknowledgements

NESDIS collaborators (Shobha Kondragunta, Xiaoyang Zhang and Pubu Ciren)
GSFC : Aeronet, GES DISC websites for satellite and model data
NRL : ICAP-MME data
ASDC : Calipso data
SUNY Collaborators (Sarah Lu, Sheng-Po Chen)
EMC AQ group (Jeff McQueen)

6 hourly Dust forecast from NGAC and ICAP at the beginning

4 June, 2015 (Dust AOD at 550nm)



6 hourly Dust forecast after 6 days

10 June, 2015 (Dust AOD at 550nm)